Case-Study Plaster Cast of the ‘Toro Farnese’: Videogrammetric 3D Reconstruction

Challenges towards Dimensions, Accessibility, Time, Complexity and Surface

Motivation and Introduction

With almost 4 m in height, the 'Toro Farnese' (Farnese Bull), now in the Archaeological Museum of Naples, is the largest sculpture known marble sculpture from antiquity. This Roman copy of a famous Hellenistic original was found in the Baths of Caracalla in Rome in the 16th century and was most likely made for this display context in the early 3rd century CE (Kunze, 1998). Due to its complexity and dimensions, only very few plaster casts were made of this sculptural group. The plaster cast collection of the Freie Universität in Berlin[1] owns such a plaster copy of the complete sculpture cast at the Berlin Gipsformerei in the 1980's. An older plaster copy, cast from the same forms as the version in Berlin in 1895 and disassembled into 55 separate parts during the GDR period, exists in the Antikenmuseum at the University of Leipzig.

The Berlin plaster cast of Toro Farnese is ideally suited as a challenging study object in terms of the dimensions (~4×4×4 m^3), the accessibility (is positioned on the wall and cannot be moved), the time (the data acquisition should take place within a time window of max. 2 hours due to changing light conditions), the complexity (the object is equipped with filigree elements) and the surface (plaster casts are poor in structure).

Fig.1: Left: Here we see the complexity of the model and the challenge. Right: The result based on a videogrammetric 3D reconstruction is very impressive.

[1] https://abguss-sammlung-berlin.de

The surface reconstruction of structurally poor objects is often a major challenge, especially when digitizing museum pieces (Farella, 2022). But it is the solution or the knowledge of the solution to major challenges that motivates people to carry out their own reconstruction work. The complete workflow of this case-study in all its details should be presented and motivated.

Methodology: Theory and Related Work

Due to the challenges involved, only the photogrammetric approach, which has become an integral part of archaeological documentation (Magnani et al., 2020), can really be considered here. However, due to the complexity of the structure and the time component, the recording strategies to be planned and thus the positioning of the camera (and the necessary overlapping of the image components) represent the limits of what is feasible here.

The related method of videogrammetry (Block-Berlitz, 2024), which has attracted more and more attention in recent years, shows its strengths in this example.

Data Recording and Process Workflow

In the first phase, various recording strategies known from flights with multicopters were planned and combined (helix flight, oriented double grid, etc.), and attention was paid to the transitions between the various video sequences. Eight video sequences were recorded with a Samsung Galaxy S20 FE 5G in 1080p with a total recording time of 42 minutes. After extracting all the individual images, a data set of almost 100 GB was created, from which the program JKeyframer[2] extracted 12382 individual images.

As part of the Archaeocopter project[3], the JKeyframer program was developed, which performs intelligent image selection and attempts to produce solutions to the min-max problem. Depending on the objective, the solutions are produced as image sets (Block-Berlitz et al., 2022). There are methods that have mainly formulated the maximization of 3D points as a goal. However, there are many solutions, i.e. sets of frames from the video stream, which lead to a coherent 3D model. Here, for example, the goal can also be formulated in such a way that not the 3D points are considered, but the number of individual images is minimized. In this way, several solutions are available that allow a sufficiently large number of images to be generated on site, which can be calculated quickly in order to check the recorded data. A set of images can then be generated to maximize the number of 3D points. We have also developed a new approach that provides a reliable measure of the number of potential matches on the graphics processing unit (GPU), resulting in significant time savings.

An iterative 3D reconstruction process in RealityCapture[4] was selected based on interim results to validate the recordings. For this purpose, the keyframes of the videos are merged step by step in the first reconstruction phase, the pose estimation. As the extracted individual images have no orientation or position data, the model was subsequently scaled correctly using real measurements on

[2] https://www.vividus-verlag.de/3d_reconstruction/index.html
[3] http://archaeocopter.de/
[4] https://www.capturingreality.com

the model. The final model, which went through RealityCapture's standard pipeline, ended up with more than 20 million vertices and almost 40 million faces.

Conclusions and Future Work

The extreme challenge of recording and 3D reconstruction of surfaces with little structure was mastered well here. The monochrome plaster cast showed sufficient visual features for the reconstruction process.

The 3D model of the Berlin Toro Farnese will be used in a current project at the Antikenmuseum in Leipzig, which aims to digitally reassemble the separate parts of its plaster cast of the Toro Farnese in a 3D model.[5] The individual parts of the cast were digitized using a handheld structured-light 3D scanner. In a next step, the missing parts of the Leipzig plaster cast will be calculated and printed in 3D for a possible physical reconstruction of the statue. The models of the missing parts will be obtained by comparing the model created from the digitally reassembled segments of the Leipzig Toro Farnese with the 3D model of the Berlin plaster cast. In addition, the Berlin 3D model shall serve as a basis to reconstruct the lost Greek original of the Toro Farnese. Baroque additions on the marble sculpture can be highlighted in color on the model. Possible additions by the Roman sculptors who copied the Greek statue, debated in Classical archaeology since over a century (Studniczka, 1903), shall be investigated and visualized in an interactive media station where students and museum visitors can experimentally blend in and out individual details (small animals on the base, supports, possibly standing female figure) on the 3D model of the statue.

The use of videogrammetry makes it possible to create 3D models even under extremely difficult conditions. The combination of photogrammetry and videogrammetry is a key to recording complex and challenging structures. Access to videogrammetric methods, such as the JKeyframer, is already available and offers a necessary addition in the context of 3D documentation. The plan is to make all the data recorded, the workflow and the final model freely available as a study object.

References

Block-Berlitz, M. (2024). *Innovations in Digital 3D Documentations of Artifacts and Archaeological Sites - Practical Guidelines to Photo and Video Campaigns Using Cameras, Multicopters, and Mini-Submarines.* Berlin, Germany: vividus Wissenschaftsverlag

Block-Berlitz, M., Heyer, D., Creutzburg, P., Suthe, L.A., Werner, P., Bommhardt-Richter, M., Rohland, H., Ducke, B., Kaiser, T., and Clemen, C. (2022). *Visual-Archaeo3D: Towards semi-autonomous graph-based videogrammetric reconstruction pipeline*, Austria, CHNT 27

Farella, E. M., Morelli, L., Rigon, S., Grilli, E., and Remondino, F. (2022). *Analysing Key Steps of the Photogrammetric Pipeline for Museum Artefacts 3D Digitisation*. Sustainability, 14(9), 5740

Kunze, C. (1998). *Der Farnesische Stier und die Dirkegruppe des Apollonios und Tauriskos.* Berlin, W. de Gruyter

Magnani, M., Douglass M., Schroder W., Reeves J., and Braun D.R. (2020). *The Digital Revolution to Come: Photogrammetry in Archaeological Practice*. American Antiquity 85(4):737–760. https://doi/org/ 10.1017/aaq.2020.59

Studniczka, F. (1903). *Der Farnesische Stier und die Dirkegruppe des Apollonios und Tauriskos*. Leipzig, E. A. Seemann

[5] https://www.gkr.uni-leipzig.de/historisches-seminar/institut/professuren/klassische-archaeologie/forschung